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Task Deliverable 5.4

Porous Pavement and Model Municipal Operations Center Demonstration Project

Final Report

SWRCB Agreement No. 06-135-559-0

September 26, 2008

San Diego River Watershed

***Project Type*: Proposition 40 Nonpoint Source Pollution Control**

***Funding Sources*: State Water Resources Control Board**
County of San Diego

Cost of Project: $2,000,000

***Grantee*: County of San Diego Department of General Services**
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List of Acronyms

BMP	Best Management Practice
CDS	Continuous Deflective Separation
COC	County Operations Center
COD	Chemical Oxygen Demand
DOC	Dissolved Organic Carbon
DGS	County of San Diego Department of General Services
EMC	Event Mean Concentrations
MFS	Media Filtration System
SAG	Stakeholder Advisory Group
SSC	Suspended Sediment Concentration
TKN	Total Kjeldahl Nitrogen
TRPH	Total Recoverable Petroleum Hydrocarbons
UCCE	University of California Cooperative Extension
ME	Medical Examiner

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1.0 EXECUTIVE SUMMARY

The County of San Diego, Department of General Services (Department or DGS) sought Proposition 40 Nonpoint Source Grant Program funds to expand the demonstration of the use of porous pavements initially funded by a Proposition 13 grant. The Proposition 40 funds were approved to continue development of a model municipal operations center by expansion of a treatment train consisting of two treatment control best management practices (BMPs) by adding three additional filtration devices. The porous pavement portion of the project included replacing approximately 54,000 square feet of additional traditional impervious pavement with porous pavement, conducting training and public outreach related to the installations, and monitoring water quality improvements associated with the installation of porous pavement and treatment control BMPs. The activities included in this project were proposed to help strengthen the County Operations Center (COC) as a regional model operations center, increase the awareness of the value of porous pavement and water quality treatment control devices, and contribute to long-term water quality improvements within the San Diego River Watershed.

The concept for this Phase II project evolved out of DGS experience with the Phase I Porous Pavement and Model Municipal Operations Center Demonstration Project and the Department's further efforts to strengthen its stormwater program. The Department is responsible for the operation of many highly impervious facilities. Much of this imperviousness is associated with high-volume public parking lots at many County facilities, particularly at several large regional centers and the COC. Because of its position as a large regional operations center, and the potential for a project there to draw attention to the problems inherent in impervious surfaces, the COC was selected as the best location to conduct a Porous Pavement and Model Municipal Operations Center Demonstration Project.

A Stakeholder Advisory Group (SAG) for this project modeled on the Technical Advisory Committee for the Phase I project was formed to review plans and reports, and contribute information from member organizations about potential applications of porous pavement and enhanced treatment BMPs within the watershed. The SAG included representation from the County Department of Public Works, the San Diego Coast Keeper, the City of San Diego, the San Diego River Foundation, and the University of California Cooperative Extension (UCCE). The SAG met twice during the duration of the demonstration project.

Approximately 54,000 square feet of existing pavement at the COC was removed and replaced with porous pavement. Three types of porous pavement were selected and installed in order to compare infiltration and runoff reduction effectiveness. The Demonstration Project also included expansion of a treatment train comprised of a Continuous Deflective Separation (CDS) device followed by a set of four media filtration units. The Department conducted a monitoring program to assess operation of these installations and conducted training and outreach to increase awareness of the problems of impervious surfaces and the potential benefits of installing best management practices to address the problem.

2.0 PROBLEM STATEMENT

The basic problem is that public and private development within urban watersheds has continuously increased the area of impervious surfaces. Approximately two-thirds of the built structure area in these watersheds is pavement. Impervious pavements reduce infiltration of stormwater and non-stormwater discharges, such as run-off from over irrigation, thus increasing urban runoff that entrains and transports pollutants to lakes, creeks, rivers, and the ocean. These pavements also reduce times of concentration, thereby increasing flood potential and hydromodification of creeks and unlined channels. They also contribute to the urban "heat island" effect that result in higher temperatures in and adjacent to urban centers.

The concept for the Phase II project arose from experience in the Phase I project. The Department of General Services wanted to gain additional experience with different mixes and configurations of porous pavement to improve its stormwater quality management at the many facilities that are highly impervious. In addition to parking lots, several facilities contain public buildings with large roof areas. The Department wanted to understand how to cost-effectively reduce urban runoff at existing and future facilities. In addition, it sought greater experience with and understanding of how best to remove constituents of concern from runoff that does occur.

Research by the Center for Watershed Protection and others has continued to demonstrate the importance of imperviousness as an indicator by which to measure the impact of land development on aquatic systems. Research on how to control both the quantity and quality of stormwater discharges from impervious surfaces has continued to lead DGS to consider the installation of porous pavement that would increase infiltration, thereby reducing excess runoff associated with highly impervious corporation yards and other surface parking. Temporary storage of stormwater within the porous pavement and underlying stone reservoir/infiltration bed will allow the water to either infiltrate into the soil or be slowly released after a storm event. Implementation of this approach to new and redeveloped parking lots could reduce discharges from DGS facilities and, if implemented widely, help to bring runoff levels within developed watersheds closer to natural levels, thereby helping to meet emerging hydromodification requirements.

Porous pavements have generally been installed in low and moderate traffic areas to promote infiltration and reduce urban runoff. This increases ground water supplies while reducing the transport of pollutants that accumulate on pavements from atmospheric deposition, automobile exhaust, tire wear, brake pad wear, leaking vehicles and other sources. Phase II of the demonstration project increased the infiltration of porous pavements in parking lots with parking and turning movements by heavy equipment as well as lighter weight cars and pick up trucks. This will permit evaluation of porous pavements under a variety of conditions.

There has been measurable improvement in the “learning curve” and a reduction of the industry and professional “fear factor” of porous pavements as a result of outreach. This is evidenced by the increase in professionals and construction firms willing to engage in the design and installation processes over the past five years. However, San Diego architects, civil engineers, contractors, and batch plant operators still have little experience with porous pavements and have been hesitant to specify or install them. Until porous pavements are widely accepted and used, development within the San Diego River Watershed and other watersheds in the county will continue to utilize impervious pavement and increase urban runoff.

3.0 PROJECT GOALS

The primary purpose of both the Phase I and Phase II Porous Pavement and Model Municipal Operations Center Demonstration Projects has been two-fold: first, to assess and demonstrate the potential water quality benefits of installing enhanced source control (porous paving) and treatment control best management practices, and second, to establish the COC as a regional Model Municipal Operations Center. The Department of General Services’ overall goal for these projects has been to demonstrate to municipal managers and elected officials the benefits and feasibility of installing porous paving and enhanced treatment facilities at municipal parking lots and corporation yards and to educate municipal employees and contractors - especially architects and engineers - about the installation of porous paving and the use of structural best management practices at municipal facilities. DGS intended that as a result of these projects it would be better able to contribute to improved water quality in the San Diego River Watershed and elsewhere in the county, an objective that would be accomplished by retrofitting existing County facilities, designing and constructing future County facilities, and influencing other jurisdictions and private entities to incorporate appropriate source control and treatment control best management practices.

4.0 PROJECT DESCRIPTION

Phase II of the Porous Pavement and Model Municipal Operations Center Demonstration Project consisted of the installation of three types of porous paving material at the County Operations Center (COC) (54,000 square feet). It also has included the installation of additional filtration devices to a treatment train of control devices at the COC. The project was designed to demonstrate how municipalities could provide leadership in improving water quality by making changes in existing facilities and improving the design and construction of future facilities. In order to enhance the value of the COC as a regional training site, the construction and assessment work has been concentrated at that Center.

4.1 Project Type

This project was funded, in part, through a Proposition 40 Nonpoint Source Pollution Control grant awarded to the County of San Diego Department of General Services by the State Water Resources Control Board. It was devised by DGS to expand a Proposition 13 project, also funded, in part, through a grant from the State Water Resources Control Board. Its purpose was to demonstrate to municipal managers and elected officials, as well as municipal employees and contractors, the benefits and feasibility of installing porous paving and enhanced treatment facilities at municipal parking lots and corporation yards.

4.2 Project Costs

Grant funds:	$1,500,000
Match funds:	500,000
Total:	$2,000,000

Match funds were provided by the County of San Diego.

4.3 Project Methodology

4.3.1 Overview of Porous Pavement Component of Demonstration Project

The County replaced approximately 54,000 square feet of traditional impervious pavement with three different types of porous paving materials at the COC. The Project managers, design engineers, and monitoring team reviewed several products and selected two porous asphalt mixes and pervious concrete as the three types of porous pavement to be installed in Phase II. These products are considered to be the most practical application for public parking areas. Design engineers and monitoring consultants for the for the porous pavement project met at the COC with the Project managers to address final site selection. During this visit, an additional test trench was constructed to assess infiltration of the expansion area. Since the results confirmed that infiltration is poor, the bottom of the stone reservoir/infiltration bed was ripped to facilitate infiltration. After the site review, the County Department of Public Works surveyed the site to provide more detailed topographic information needed for design. The final site was along the northern edge of the COC, north, northeast, and northwest of Building 7.

Installation of porous pavement was completed October 10, 2007. Three porous pavement product types were installed: pervious concrete (approximately 12,100 square feet) and two mixes of porous asphalt totaling approximately 41,900 square feet. The pervious concrete was installed over a separate monitored stone reservoir/infiltration bed. Unlike the pervious concrete in Phase I, this pervious concrete was installed using a vibratory screed. In addition, it was kept covered and hydrated for seven days, rather than the two days specified in Phase I. Comparison of the two pervious concrete test plots over time will facilitate evaluation of the alternative installation specifications. The porous pavement component of the project also includes the testing of two additional porous asphalt mixes, PG 64-10 and PG 70-10. A portion of each mix was installed over a geogrid to test differential durability over time. The two mixes of asphalt are over a common monitored stone reservoir/infiltration bed. This reservoir also receives roof runoff from approximately 26,000 square feet of roof. This addition to the project is monitored separately in order to assess the contribution of pollutants from atmospheric deposition to runoff from the site. In addition, lysimeters were installed under each of the stone reservoirs/infiltration beds to help evaluate infiltration from the stone reservoirs/infiltration beds into the underlying soil profile. The suction lysimeters were used to sample pore water in the unsaturated zone of the soil profile. Water collected in the lysimeters was chemically characterized to assist in examination of the transport and fate of various constituents, especially metals, as water collected in the infiltration basins passed through the underlying soils. Approximately 37,600 sq. ft. of existing parking lot was prepared to function as a replacement "reference area" for baseline monitoring purposes since the reference area used during Phase I and the first wet season of Phase II was disturbed by construction of a new building.

4.3.2 Overview of Treatment Train Component of Demonstration Project

In planning for the Phase I demonstration project, the Department looked at various treatment controls to address constituents of concern at the COC that were not fully addressed through pollution prevention and source control. Because of an initial emphasis on retrofitting devices into existing facilities, the focus was on proprietary structural treatment controls that could be installed underground.

This phase of the Demonstration Project involved the installation of a treatment train to capture gross pollutants from stormwater discharges from rainfall events up to 0.2 inches per hour and to filter out very small suspended solids and dissolved constituents of concern from the first flush of these stormwater discharges. A Continuous Deflective Separation stormwater pollution control device and a media filtration system, both manufactured by CDS Technologies, Inc. were installed.

The CDS unit installed at the COC uses a 2,400-micron screen that permanently captures material down to about the size of a match head (about 2.4 mm). Floatables and neutrally buoyant materials are trapped in a separation chamber by the screen while negatively buoyant debris settles into a catchment sump that extends to a depth almost eight feet below the storm drain. In this case, the bottom of the sump is almost 20 feet below the surface of the parking lot because the storm drain is deep. The unit also has an oil baffle capable of capturing up to 80% of free oil and grease. In addition, sorbent booms were installed on the water surface to capture free oil. Use of these booms is expected to result in removal of up to 90% of the free oil and grease in stormwater runoff from the site.

The Phase II expansion of the treatment train component of the Demonstration Project included the installation of one additional Media Filtration System (MFS) filtration unit and two StormFilter media filtration units adjacent to the original MFS unit near the eastern edge of the COC just before stormwater from the site enters the City of San Diego storm drain system. The MFS and StormFilter systems are very similar flow-through filtration systems using rechargeable media-filled cartridges and storage sumps to capture and retain pollutants. The MFS unit was designed by CDS Technologies and the StormFilter unit was designed by Stormwater Management, but both products were taken over by Contech when it acquired both CDS Technologies Stormwater Management. Both types of systems are housed in underground vaults. The canisters in the MFS unit are taller than those in the StormFilter units, allowing a smaller footprint.

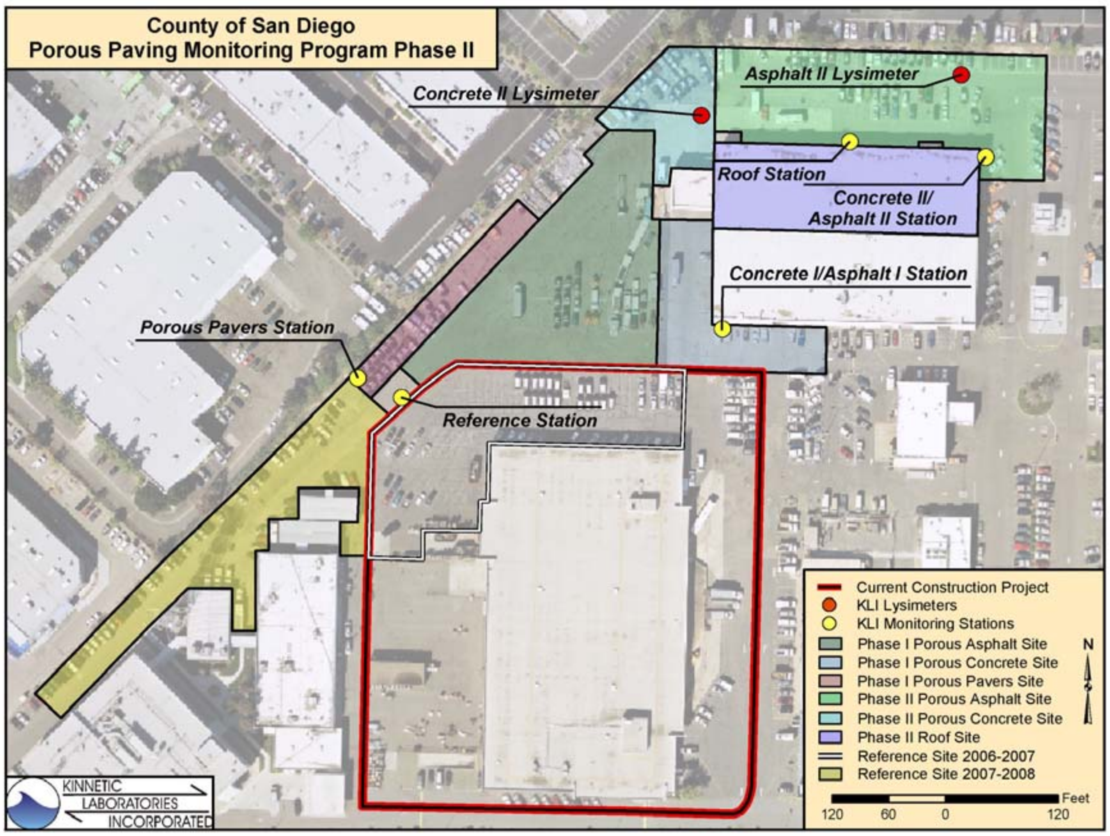
Installation of the expanded treatment train was completed on August 26, 2007. The four-unit filtration system was designed to treat 6 cfs of stormwater after the flow goes through primary treatment in the Phase I CDS unit. In addition, monitoring equipment was installed to test the influent and effluent of each of the four filtration units to accommodate the comparison of different filtration media over time. Initially, one MFS unit and one StormFilter unit had perlite media in their canisters to compare the effectiveness of the two types of units using the same media. A mixed perlite-zeolite medium was installed in one of the other filters, and organic medium targeting metals removal is in the fourth filter.

4.3.3 Project Monitoring

Although the duration of Phase II monitoring was insufficient to make definitive statements about the water quality improvements possible through the installation of porous pavement and treatment trains, the three types of porous pavement and the CDS/media filtration treatment train expanded during Phase II were monitored to develop preliminary information on their performance. This monitoring program focused on assessing how effective the treatment control devices are in removing oil and grease, sediment, trash and debris, and dissolved constituents such as soluble metals, organics, nitrogen, and phosphorus.

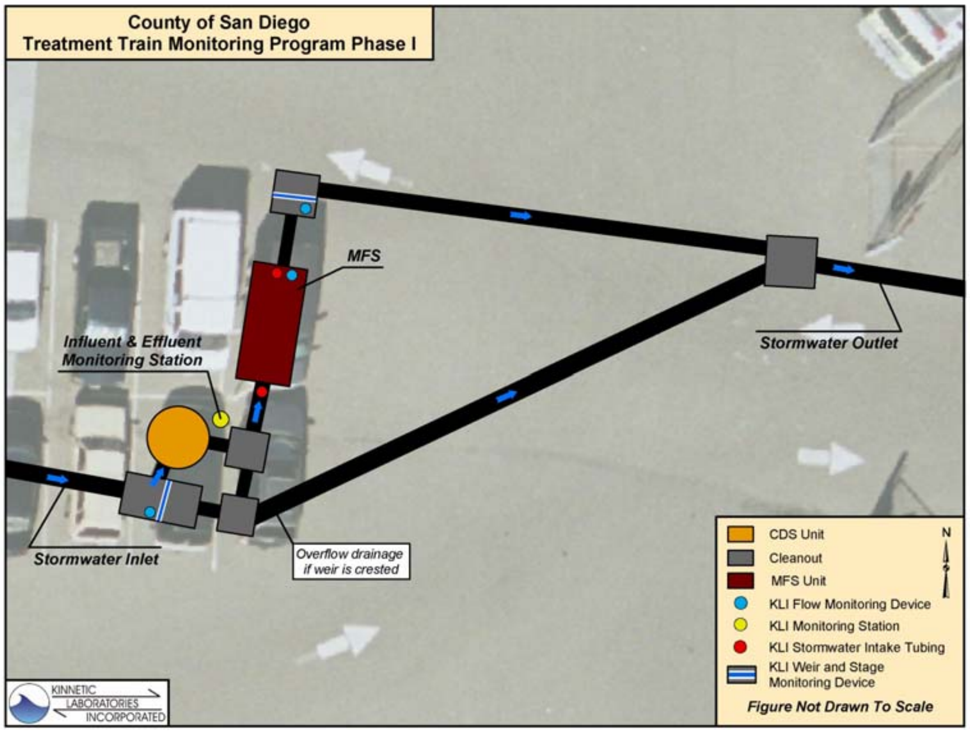
Monitoring stations were established and re-established during Phase II at locations where subsurface drains exit each of the pavement test sites and a reference site that drains a similar section of parking area with standard impervious paving. Phase II monitoring compared discharges from the initial three porous pavement test sites, the two additional test sites, and the reference areas in order to measure flow reductions, hydrograph modification, and reductions in both pollutant loads and concentrations. Rain gauges were incorporated into monitoring stations at two of the sites to provide accurate measure of stormwater volumes associated with each site. A rain gauge installed at the nearby treatment train BMP test site and an ALERT Kearny Mesa rain gauge on the COC site were used to supplement measurements at the porous pavement sites and provide back up, if necessary. Monitoring of the Phase I porous pavement installation was continued by the Phase II grant.

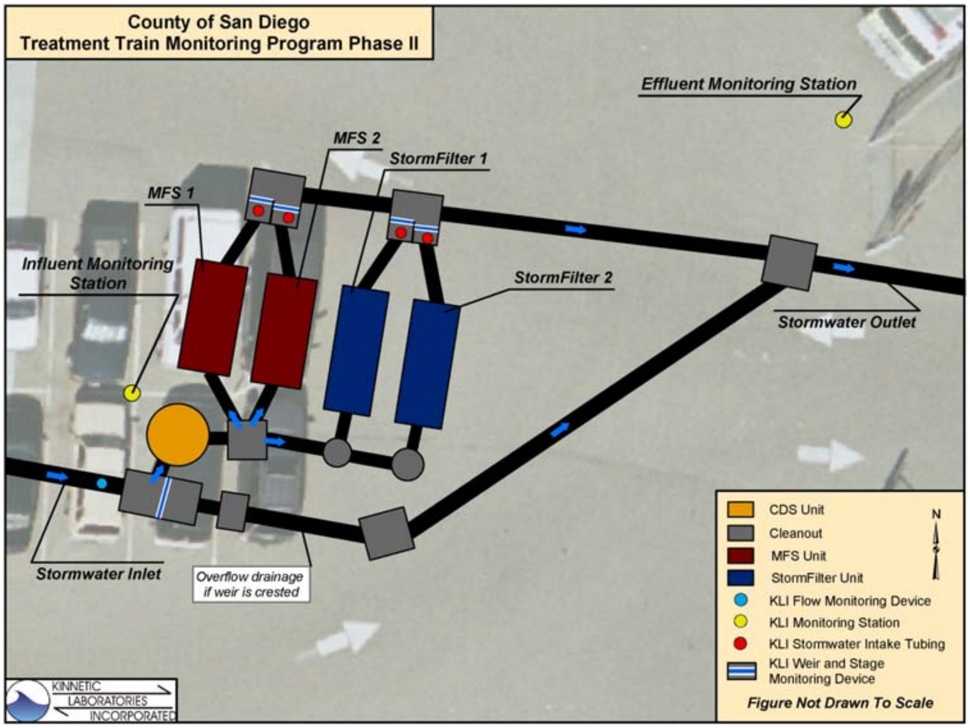
The design engineer and site project manager coordinated during Phase II to assure that site design and configuration changes required during the construction process did not impair hydraulic isolation of the sites and the ability to obtain precise measurements of stormwater discharge. This concrete approach channel and Parshall flume used to monitor flow from the reference areas was constructed during Phase I.



Monitoring of the treatment train continued to include characterization of the gross pollutants and sediment load removed by the CDS unit and any reduction in pollutant concentrations and loads by the media filtration system. The design of the project monitoring was included in Sampling and Analysis Plans submitted to the Regional Board, and the results of the monitoring are contained in Appendix 1.

The continued monitoring program in Phase II has been generally consistent with the monitoring program established during Phase I. The differences involve the addition of a roof runoff site to examine contaminants associated with both atmospheric deposition and roof top sources, and the addition of lysimeters to examine infiltration and changes in water quality as the stormwater is infiltrated.





Storm tracking and monitoring under Phase II of the Demonstration Project began in October 2007, but monitoring equipment to record rainfall and runoff could not be installed until mid-November due to construction delays. Total wet season rainfall at the County Operations Center from October 2007 through April 2008 was measured at 10.58 inches at the Kearny Mesa ALERT site and 8.15 inches at the porous paving reference site. Most of the rainfall for the past season occurred in January and early February. No rainfall events occurred between February 24, 2008 and the termination of monitoring on April 30, 2008. Most of the monitoring equipment was removed from the site in mid-May.

As of June 2008, water levels in the Phase II porous concrete site indicated almost no infiltration. The Department is considering how best to remove and/or reuse the water prior to the next rain event. Two options being considered are reuse on site for dust control or transferring the water to the Phase II porous asphalt infiltration basin where it will be able to infiltrate. A water sample was analyzed and final determination of removal and/or reuse will be made based on that analysis.

The final field task was sampling of the CDS sump units. This took place on July 21, 2008 in conjunction with CONTECH Stormwater Solutions.

The monitoring design and results of the monitoring program are discussed in detail in Appendix 1.

5.0 TRAINING AND OUTREACH

The Department's training and outreach component was undertaken after installation and monitoring of the treatment train and porous pavement were completed. Phase II training and outreach included presentations by DGS staff and consultant Richard Watson at a Low Impact Development Workshop sponsored by the County of San Diego, in cooperation with the American Society of Civil Engineers and several other municipal and private sector entities.

DGS contracted with San Diego Coastkeeper to provide assistance in performing outreach pertaining to the County Operations Center demonstration project through the first half of 2008. A number of groups were identified and targeted for participation in the tour, including stormwater co-permittees, city and county planners, engineers, environmental scientists, and managers. These groups were recruited through co-permittee stormwater meetings, the California Nonpoint Source Conference, and the Ocean Protection Council, Filterra, and American Planning Association Low Impact Development workshops. The objective was to engage a wide variety of professional stakeholders in order to convey lessons learned and technology transfer for the purpose of implementing these technologies, where appropriate, in other areas across the County. The tours have been successful and the Department intends to continue the outreach in order to meet the high level of interest that has been generated. This outreach included discussions about how to address the "fear factor" among potential adopters of porous pavement techniques and understanding of how to implement these technologies on a variety of scales.

6.0 CONCLUSIONS

6.1 Porous Pavement Runoff Reduction/Infiltration

Water levels in the infiltration beds of all porous pavement treatment sites were continuously monitored throughout the project to determine how the infiltration basins responded to both individual events and the effects of multiple events throughout the season. Given initial measurements taken with a double-ring infiltrometer during the early design stages, it was expected that water levels within the basins might gradually increase after a series of events due to minimal infiltration rates.

Substantial differences were evident among the five infiltration beds. Examination of the declines in water levels within each of the infiltration beds requires some discussion of potential pathways out of the infiltration beds that might cause water levels to drop for reasons other than infiltration. Some of the differences among sites were clearly attributed to leakage out of the infiltration beds. Some of these pathways were identified early and corrected while others were identified after closer review of the construction process.

Leakage was first discovered at the Phase I Pavers site. Water was leaking under pressure through the joint between the effluent pipe and the catch basin used for sampling overflow from the system. Being downstream of the monitoring point, this discharge was not quantified. The leak was repaired in late 2007 in conjunction with installation of the Phase II sites.

Review of construction photographs also indicated a likely connection between the Phase I asphalt and concrete infiltration beds. The Phase I asphalt discharge pipe passed through the berm between the two beds and over to the monitoring point at the southwest corner of Building 7. Rock bedding placed around the drainage pipe is believed to have provided a conduit between the two beds. The rock bedding used for drainage pipe going from the monitoring station to the main storm drain is thought to be another possible route for water to leave the Phase I concrete infiltration bed. At this time, it is unknown whether this provides a significant pathway for water from the Phase I concrete site and whether water can migrate along the bedding of the main storm drain. However, there is some evidence that it does not provide a significant pathway for water at this site.

During a large storm event in early 2007, water levels in the Phase I asphalt infiltration basin came within ¾ of an inch of topping the weir and discharging to the storm drain. The rates of rise in water levels the adjacent Phase I concrete infiltration basin were identical to those observed in the Phase I asphalt infiltration basin. When the storm ended, infiltration rates (as measured by the decline in water level over time) were substantially different. From the time of the peak water level was reached in each basin, it took 14 hours for the water level to drop 6 inches in the asphalt basin compared to 19 hours in the concrete basin. The more rapid decline in water levels in the Phase I asphalt basin indicates that water was not simply passing into the Phase I concrete basin and down the bedding of the existing storm drain system. The more rapid drop in water levels within the Phase I asphalt implies that water was infiltrating faster than in the Phase I concrete. In addition, the slower infiltration in the concrete infiltration basin indicates that water was not rapidly leaving the site. Despite some questions as to whether some stormwater may have been directed outside the infiltration basin boundaries, no overflows were encountered.

The Phase II porous paving installations were designed to eliminate potential pathways between infiltration basins and through the rock bedding used for the drainage systems. Anti-seep collars were installed between the Phase II concrete and asphalt infiltration basins at the point where pipes went through the berm and at a point just past the junction of the drain pipes from the two infiltration basins joined to the main storm drain. Despite these improvements, leaks into the drainage pipes were identified during early events at both the Phase II asphalt and concrete sites. The leaks were initially identified during storm events in December 2007 at the monitoring stations as continuous low flows occurring before water levels in the infiltration basins had reached levels necessary to overflow. The Phase II concrete site had a leak downstream of the control weir at the junction of the pipe with the concrete utility box. The Phase II asphalt site had a leak in the joint between the pipe and the sampling catch basin. Repairs at both sites were delayed to allow water levels to drop low enough to repair the pipes in a dry environment. The first attempt at repairing the leak occurred on 14 January 2008 but this initial attempt failed causing further delays. Final repairs were conducted on 23 January 2008. Water infiltrated slowly at this site but it did show evidence of infiltration. It took a period of several weeks of dry weather following a series of rainfall events for water to no longer be detected in the infiltration bed.

The Phase II concrete site presented a different situation. Once the leak was repaired in mid January 2008, water levels progressively increased in the Phase II concrete nearly reaching the top of the weir during two storm events. However, this site never discharged. Each time water levels approached the top of the weir, levels would slowly drop. After the last rainfall, water levels in the Phase II concrete infiltration basin slowly dropped and stabilized at a depth of 0.86 feet.

Overall, no water was recorded as topping the weirs at any of the monitored porous paving sites.

6.2 Treatment Train

A total of eight storm events were monitored for rainfall and flow volumes during the 2005/2006-storm season of Phase I. Flow was monitored through the CDS unit for a ninth event that occurred after the end of the official monitoring season. Monitoring was continued at this site to allow all runoff to be quantified prior to removal and assessment of gross pollutants from the CDS sump. Full analytical testing was conducted on the first three events. All subsequent events that occurred up through the end of the monitoring season on April 30, 2006 were monitored for rainfall and flow.

Stormwater discharges exceeding 7.5 cfs were intended to bypass the entire Treatment Train. Since the initial configuration of the Treatment Train had only a single MFS unit with a design capacity of 1.75 cfs, much of the stormwater treated by the initial CDS unit also had to be redirected around the MFS unit. This condition was modified during Phase II when an additional MFS unit and two StormFilter units were installed. Bypasses of the Treatment Train were uncommon and only occurred during brief periods when flow spiked due to particularly intense rainfall. During the Phase I rainy season, 96.5 percent of the stormwater runoff from the COC was treated by the CDS unit. Roughly 33 percent of the water treated by the CDS unit entered the MFS unit (the second component of the Treatment Train). The remainder was discharged back to the main storm drain and discharged to the municipal storm sewer system.

The MFS unit installed during Phase I also experienced internal bypasses that may have been partially influenced by backpressure from the downstream weir. This MFS unit treated 73 percent of the water that entered the system. Overall, approximately 25 percent of all stormwater runoff from the COC received full treatment by the CDS and MFS units. A modified control box was installed during Phase I in the MFS unit to provide the ability to make the fine adjustments needed to limit bypasses and the new MFS unit installed under Phase II of the program also has the modified control box.

During individual storm events in Phase I, the percent of influent flow to the MFS that was effectively treated ranged from 64 to 95 percent of the water entering the unit. These percentages varied due to differences in duration and intensity of storm events. CDS has modified the MFS unit to improve performance of the system.

7.0 WATER QUALITY BENEFITS

7.1 Porous Pavement

Stormwater quality was measured during four events at the roof reference site, three events at the Phase I references site and three events at the Phase II reference site during the past two years. Phase I and II parking lot reference data were separated due to potential biases caused by the overflow and dewatering of the adjacent Medical Examination building construction site.

All porous paving BMPs examined were considered successful in preventing nearly 100 percent of the metals and other contaminants from discharging to the San Diego River through the municipal storm drains over the course of the two-year study. As noted earlier, some water was lost from the Phase I porous pavers and Phase II porous concrete and asphalt infiltration basins as the result of leaks in the drainage pipes but the exact amount of these losses could not be quantified. During the 2006/2007 season, 4.5 inches of rain at the Phase I porous paving sites prevented over 686,000 liters (0.56 acre feet) of runoff from discharging to the storm drain system. With the Phase II improvements and increase in annual rainfall, the combined Phase I/II porous paving sites prevented over 2,593,000 liters (2.1 acre feet) from discharging to the storm drain.

The seasonal mean Event Mean Concentrations (EMC) for runoff from the reference area, the areal coverage of each porous treatment, and annual rainfall were used to estimate load reductions achieved by each type of porous pavement for each year. A summary of the estimated load reductions for the past two wet seasons is provided in Table 1.

Table 1. Summary of Load Reductions resulting from the Porous Paving Treatments during the 2006/2007 and 2007/2008 Wet Seasons.

Constituent	Phase I Sites 2006/2007 Total Load Reduction (Kg)	Phase I and II Sites 2007/2008 Total Load Reduction (Kg)
SSC	16	209
>63 microns	4.2	34
<63 microns)	15	175
TSS	17	217
COD	34	87
DOC	9.6	11
Total P	0.10	0.26
Ortho-P	0.058	0.10
Ammonia-N	0.24	0.45
TKN	0.89	1.9
Nitrate-N	0.26	0.68
Total Cadmium	0.00047	0.0033
Diss. Cadmium	0.00025	0.0010
Total Copper	0.011	0.31
Diss. Copper	0.0082	0.090
Total Lead	0.014	0.19
Diss. Lead	0.0021	0.019
Total Zinc	0.060	4.7
Diss. Zinc	0.034	1.1
Calculated Values		
Oil & Grease(COD)	3.8	13
Oil&Grease(DOC)	2.8	3.4

The following equations were used to calculate estimated load reductions for the project. The calculation for total phosphorus during the 2007/2008 season is provided as an example. The first equation illustrates the calculation of the total volume of stormwater directly impinging on the five porous paving areas.

$$V_{PP} = (C1_A + C2_A + PP_A + A1_A + A2_A)*R*28.32$$

$$V_{PP} = (14{,}936\ ft^2 + 12{,}100\ ft^2 + 7{,}896\ ft^2 + 41{,}092\ ft^2 + 41{,}900\ ft^2)*0.6408\ ft * 28.32\ L/ft^3 = 2{,}140{,}020\ liters$$

where:

V_{PP} = volume of annual rainfall directly on Porous Paving Surfaces (liters)

$C1_A$ = Area of Phase I porous concrete (ft^2)

$C2_A$ = Area of Phase II porous concrete (ft^2)

$A1_A$ = Area of Phase I porous asphalt (ft^2)

$A2_A$ = Area of Phase II porous asphalt (ft^2)

PP_A = Area of Phase I porous pavers (ft^2)

R = average annual rainfall (inches)

28.32 = conversion constant from ft^3 to liters

The annual volume of water impinging on the roof reference area was then calculated separately using the same basic equation:

$$V_{RR} = RR_A * R * 28.32$$

$$V_{RR} = 25{,}000\ ft^2 *0.6408*28.32 = 453{,}686 \text{ liters}$$

where:

V_{RR} = volume of annual rainfall directly on the roof reference area (liters)

RR_A = Area of roof reference site (ft2)

The next equation illustrates the calculation of the total loads that are expected to be eliminated in an average rainfall year as a result of the completed parking lot improvements. The median EMC for the parking lot reference area was used for all porous paving surfaces and the median EMC for the roof reference area was used for runoff from the roof.

$$L_x = (mPLR\_EMC_X * V_{PP}) + (mRR\_EMC_X * V_{RR})$$

$$L_{TP} = (0.00014 g/L * 2{,}140{,}020 \text{ liters}) + (0.000057 g/L * 453{,}686 \text{ liters}) = 325 g \text{ P}$$

where:

$mPLR\_EMC_X$ = Median EMC of constituent of concern X at the Parking Lot Reference Site converted to g/L.

mRR_EMC_X = Median EMC of constituent of concern X at the Roof Reference Site converted to g/L.

L_x = Estimated pollutant load reduction in (g) for constituent of concern X.

TP = Total Phosphorus

7.2 Treatment Train

Rainfall and runoff was measured continuously at all monitoring sites from January 2007 through April 2008. A total of eight storm events were monitored for rainfall and flow volumes during the 2006/2007 storm season while the treatment train was still in the Phase I configuration. An additional 16 events were characterized during the 2007/2008 storm season after all Phase II modifications were completed.

Stormwater discharges exceeding 7.0 cfs were intended to bypass the entire treatment train. Since the Phase I configuration of the treatment train only had a single MFS unit

(MFS2) with a design capacity of 1.75 cfs, much of the stormwater treated by the initial CDS unit also had to be redirected around the MFS unit. Between January and April 2007 the CDS treated 95.4% of the runoff from the COC. About a third of the runoff was directed into the MFS unit but only 68% of the water entering the MFS unit was fully treated. The remainder was discharged through the internal bypass. During individual storm events in early 2007, the percent of influent flow to the MFS that was effectively treated ranged from 45 to 95 percent of the water entering the unit. These percentages varied due to differences in duration and intensity of storm events.

With completion of the Phase II improvements, all runoff passing through the CDS unit was subsequently passed through the four filtration units. During the 2007/2008 season 99.4 percent of the runoff from the COC passed through the treatment train. This totaled 696,695 cubic feet of water.

The removal of gross pollutants by the CDS unit provided important pretreatment necessary for the filtration units. The filtration units were intended to provide further treatment of the stormwater by filtration of the finer particulates and contaminants that might be associated with the fine fraction. Data from the 2007/2008 season demonstrated that the CDS unit was effective at removing the coarse material but it also removed a substantial amount of fine material (Table 2). A total of 618 Kg of sediment (dry weight) was removed from the CDS unit at the end of the 2007/2008 wet season. Over 2/3 of the sediment removed from the unit was less than 63 microns in size. The fine sediments present in the CDS unit were attributed to sediment from the construction area for the Medical Examiner building. Dewatering was necessary between storm events due to lack of infiltration and the need to prevent discharges during storms when high flows would increase sediment loads.

Sediment removed from the CDS sump at the end of the 2007/2008 season also had very different concentrations of key constituents of concern relative to the sampling conducted at the end of the 2005/2006 season. Concentrations of oil and grease and TRPH were 20 to 30% of concentrations reported during the initial sampling event. The concentration of total phosphate –P was less than 15% of concentration from 2006 and TKN was close to 10% of the previously reported level. Ammonia-N was the only nutrient that increased substantially between the two periods. The concentration of ammonia-N increased from just 2.3 to 64 mg/Kg.

Concentrations of metals in the sump sediments were not dramatically different from background soils (Bradford et al. 1996) from San Diego County (near the intersection of the I-5 and I-805 freeways). Soils at this background site were classified as clays. Concentrations of cadmium, copper, lead and zinc at the background site were 0.11, 36.6, 57 and 172 mg/Kg-dry, respectively. Cadmium, copper, lead and zinc in the sump samples were 0.33, 54, 45 and 220 mg/Kg-dry, respectively.

Table 2. Chemical and Physical Properties of Materials removed from the Sump of the CDS Unit in 2007.

PARAMETER	2007/2008
CDS SUMP TREATMENT STATISTICS	
Total Treated Water Volume (Liters)	20,129,064
Total Rainfall (inches) – KEA rain gage	8.15
Total Sump Material Removal (Kg – wet)	2565
Total Sediment (≤4.75 mm; Kg – dry)	618
CDS SUMP SEDIMENT PHYSICAL CHARACTERISTICS	
Sediment Particle Size (percent)	
Gravel	3.1
Sand	31.0
Silt	13.2
Clay	52.7
SEDIMENT CONTAMINANT CONCENTRATIONS	
Percent Solids (% wet weight)	25.4
Oil & Grease (mg/Kg – dry)	730
TRPH (mg/Kg – dry)	240
Total P (mg/Kg – dry)	890
TKN (mg/Kg – dry)	120
Ammonia-N (mg/Kg – dry)	64
Total Cadmium (mg/Kg-dry)	0.33
Total Copper (mg/Kg – dry)	54
Total Lead (mg/Kg – dry)	45
Total Zinc (mg/Kg – dry)	220
SEDIMENT CONTAMINANT MASS (Grams)	
Oil &Grease	451
TRPH	148
Total P	550
TKN	74
Ammonia-N	40
Total Cadmium	0.20
Total Copper	33
Total Lead	28
Total Zinc	136

The most substantial information on performance of the treatment trains was obtained while the system was still in the Phase I configuration with the CDS unit and a single MFS unit (MFS2) equipped with the internal bypass. The database consisted of eight storm events measuring influent and treated effluent from the system. A paired T-test indicated that concentrations of total SSC, both fractions of SSC, TSS and COD were all significantly ($p \leq 0.05$) reduced in the MFS unit. Correspondingly, total copper, lead and zinc were also significantly reduced by the filtration system. Three soluble nutrients (orthophosphate-P, ammonia-N, and nitrate-N) showed significant increase in concentration. Increases in concentrations of these nutrients are suspected to be due to degradation of organic material trapped in the vault and filters that get flushed out with storm events.

Although removal of total copper, lead and zinc was statistically significant, only lead showed evidence of substantial improvements in the final effluent. The regression suggested that effluent concentrations were roughly 55% of influent concentrations. Given the strong tendency for lead to associate with fine particulates, it was not surprising to see effective treatment by a filtration BMP.

As with the low, but statistically significant removal of total copper and zinc, the increases in soluble nutrients were minor (10-20 percent) and occurred at low concentrations. Neither the small increases in dissolved nutrients nor the small decreases in total metals should be considered characteristic of this BMP at higher loading rates.

Due to only three monitored storm events in the Phase II configuration, performance of the filtration systems could only be qualitatively examined. The monitoring data provided evidence of removal of solids by all filtration units including MFS2 where water was not being filtered properly due to faulty installation of filter canisters. Some degree of treatment was apparently provided by settling within the vault. The post season inspection by the vendor indicated that sediment was present in the vault. The coarse fraction of SSC which consists of particles greater than 63 micron was most effectively removed. Most of this fraction would be expected to have been removed by the CDS unit which provided pretreatment.

This initial data set does suggest the CSF media in SF2 was a source of very small concentrations of both total phosphate-P and orthophosphate-P. Evidence of export was strongest for orthophosphate since the other three media filters all had effluent concentrations essentially equal to the influent concentrations. Dissolved organic carbon (DOC) also appeared higher in effluent from the CSF media but additional data would be necessary to verify this. An increase in DOC would be consistent with observed increases in phosphorous. The source of phosphorous and possibly DOC is likely due to some breakdown of the CSF media.

The monitoring data suggest some removal of total metals at higher concentrations at all monitoring sites. Lower concentrations of total metals were consistent with observed decreases of solids. Overall there was very limited evidence of substantial improvement in water quality as a result of the filtration units. In cooperation with the vendor and monitoring consultant, the Department is continuing to investigate the circumstances of the new filter systems performance. Dewatering of the ME construction site, to some extent, may also have been a contributing factor to the performance of the filtration units.

8.0 LESSONS LEARNED

The Department has gained significant insight into the processes of constructing and monitoring three types of porous pavements and one type of treatment train (with multiple filtration media). Generally, the porous pavements have effectively reduced urban runoff, and, with the exception of one unit in which the filters were not installed properly, the filtration units filtered stormwater and non-stormwater discharges from the County Operations Center. The effectiveness of both the porous pavements and the treatment train are discussed in detail in Appendix 1.

Most of the lessons learned during Phase II were related to engineering, construction, and construction oversight. With respect to engineering of the porous pavement, coordination and oversight would have been improved if the engineer had had a local office and could have provided continuous oversight of the grading, installation of basins and piping, installation of the stone reservoir/infiltration bed, and installation of the pavements. With respect to the treatment train, the Department learned that using a separate engineering firm to design the treatment train in close consultation with the manufacturers - rather than using the manufacturer's engineering staff - could improve engineering design. Multiple technical reviews of designs could prevent design errors or overlooked elements.

Construction and construction oversight contributed many of the lessons learned. Installation of pervious concrete is labor intensive and must be done carefully. The concrete industry has now established a certification process for installation of pervious concrete. The Department's experience during both phases of the demonstration project strongly indicates that future contracts for installation of pervious concrete require certification of the contractor. A second construction lesson from the project is that piping installations should be pressure-tested before being covered. Monitoring programs and infiltration, in particular, can be adversely impacted by leaks in the system.

One lesson from the treatment train component of the project is that any installation of a treatment train involving manufactured components should involve extensive on-site participation by the manufacturers during construction. Components installed by contractors or sub-contractors should be inspected, tested, and certified by the manufacturer. The faulty installation of filters in one of the filtration units in the treatment train was not discovered until after the 2007-2008 wet season. This resulted in faulty monitoring data from that unit of the filtration system.

One major construction lesson learned is that construction budgets for porous pavement and treatment train installations should contain large contingency components. Contractors are not yet well versed in installation of such projects and cost overruns are common.

With respect to monitoring, one major lesson that has been reinforced is that effective monitoring is greatly influenced by design and construction. Monitoring of complex, multi-chambered systems can be compromised by the absence of anti-seep collars or barriers at critical locations and the lack of critical attention to joints between catch basins and pipes. The functioning of porous pavement reservoirs and the operation of treatment trains can be compromised by leaks into or out of catch basins and pipes. Such leaks can also make interpretation of monitoring results difficult. A second monitoring lesson is that bypasses in filtration systems that are so equipped should be monitored in order to verify that units are meeting specifications and as an indicator of potential clogging of filter cartridges. Another lesson is that assessment of infiltration and water changes within basins under porous pavements could be improved through the installation of multiple lysimeters at different depths within the same basin. Lastly, Phase II has demonstrated that quantification and sampling of sediments trapped in filtration vaults would provide more complete sampling from a mass balance approach.

APPENDIX I:

County of San Diego Model Municipal Operations Center, Porous Paving and Treatment Train Water Quality Monitoring Program, Final Report

Appendix II:

Photo Documentation

Appendix III:

Porous Pavement Operation and Maintenance Protocol

Appendix IV:

COC Maintenance Experience

Appendix V:

Deliverables

QuickTime™ and a
decompressor
are needed to see this picture.

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